NATIONAL WEATHER SERVICE TUCSON, ARIZONA

Spring/Summer 2013

Volume 19, Issue 1

COYOTE CRIER

SKYWARN NEWSLETTER SERVING THE WEATHER SPOTTERS OF SOUTHEAST ARIZONA

Ensemble Forecasting—Throwing Darts With Skill

John Brost, Science and Operations Officer

Inside this issue:

I'm sure you have all heard this story; "A butterfly flaps its wings somewhere in China and two weeks later a tornado hits Oklahoma". This is commonly known as the "Butterfly Effect". The main concept is fairly simple. A subtle change in an initial condition (what is happening right now) can produce significant future impacts. The above example may be stretching the concept to its extreme, but we see this concept in action every day in the world of operational forecasting. One method of capturing the multiple potential outcomes from changing initial conditions is to run an "ensemble".

Before I explain an ensemble, I'd like to describe weather models in general. The atmosphere is governed by physics and chemistry. We know that what goes up must come down and we know how various elements interact to produce sensible weather like rain, temperature and wind. In fact, we know so much about the atmosphere that we can simulate the real world with a computer model. The computer model is produced using extremely complex equations that describe motion, energy, and the mixing properties of various elements. Exceptionally powerful computers then run millions of calculations to show how these factors change over time. The end result is a computer model that displays the atmospheric conditions up to ten days into the future (some even further).

That would describe just one model. We will call that "Model A". Now Model A may be a great model most of the time, but occasionally Model A gets confused. Why does Model A get confused? There are several reasons:

1. The atmosphere is very large and complex.

2. Our models are not perfect. Due to the complexity of the atmosphere and our computational limits, we have to make assumptions in the equations that generate the model. Some of these assumptions can lead to degraded accuracy with time.

3. We cannot know the exact initial conditions everywhere on the planet in three dimensions. We would need a network of weather stations placed every mile or so across the entire planet just to sample the ground conditions. This would not even account for the conditions above the ground.

In this case, if we only had access to Model A, then sometimes we would receive an incredibly accurate forecast. Other times, Model A might produce a bad forecast. We do not like to place all our bets on one model. This is just like investing. If you put all your money in one stock then sometimes you will win big, but other times you would lose big. So you diversify. We diversify in the world of meteorology by using multiple different models and we also use something called an ensemble.

Imagine, if you will, that you were throwing darts (at a dartboard). As the thrower, you represent a weather model and the dartboard represents a possible outcome. The initial conditions are your distance from the board, your stance, your arm angle, the speed at which you throw the dart, and your release point. These factors help determine where your dart will eventually land. If you were a highly tuned computer, you could replicate all of these initial conditions with ease. However, as a human, the chances are these initial conditions will change slightly each time you throw a dart. These modifications will likely result in your dart hitting a different place on the board. In this example, you could produce many possible combinations of initial conditions. The atmosphere is very similar, except the initial conditions, like temperature, pressure, wind speed and humidity, are constantly changing.

Now imagine, if you will, that another person steps up to the line to throw darts. This person represents a new model. They have different physical properties. Maybe they are shorter or stronger, or maybe they use different darts with unique weight or balance. Even if they try to replicate your initial conditions, the chances are the new thrower will land their darts in a different location on the board.

If each person only threw one dart, then that would represent just two different models. You better hope they are accurate dart throwers or your forecast could be wrong.

For an ensemble approach, each dart thrower would throw ten or twenty darts at the board (each single dart would be considered a member of the ensemble). That way, you could identify the range of possible outcomes based on changing the initial conditions or model physics. In essence, you would simulate the butterfly effect.

I know using a dart throwing analogy to explain weather forecasting is dangerous territory because it might imply that there is no skill in the weather models. The reality is quite opposite. In our dart analogy, the dart throwers would both have many years of experience throwing darts. In addition, they would have completed many decades of research indicating the proper method of throwing darts or the best dart to use. Plus, they would understand what constitutes a good throw from a bad one and then they could eliminate the bad throws.

Our dart throwers would have a great deal of skill especially if they were relatively close to the board. If you moved the board back two feet after every round of throwing darts, then you would simulate a longer range forecast. You would likely notice the darts slowly spreading out over the board with time. This is called "ensemble spread". If the ensemble produces a lot of spread, then you would have lower confidence in the forecast (as it would indicate many different outcomes). Conversely, if each ensemble member is tightly packed together, then you would have high confidence in the forecast (as it would indicate the models are converging on one outcome).

In operational forecasting, we use both individual models and ensembles. Our goal is to have the best understanding possible of the range of outcomes based on our current conditions. That way, we can articulate potential threats to the public or to decision makers who are responsible for public safety. These models and ensembles are becoming more skillful with time as computing power increases and our understanding of the atmosphere improves. We will still have challenges observing the weather everywhere on planet Earth, but our forecasts continually increase in both accuracy and precision.

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Major Winter Storm Brings Snow to Southeast Arizona...Including the Tucson Metro Area

Greg Mollere, Senior Forecaster and SKYWARN Spotter Training Coordinator

On the morning of February 20, 2013 a 537dm (decameter) low was over southern California just east of the Los Angeles area as seen in Figure 1. Temperatures at 500mb (millibars), in the vicinity of the low, were minus 32 degrees Celsius. As the day progressed, the low moved east and by late afternoon on the 20th a 541dm (decameter) low was over south central Arizona as seen in Figure 2. Temperatures at 500mb near the low at that time were still at minus 32 degrees C. By early morning on the 21st the low had transitioned from a closed low to an open wave and was positioned over southeastern Colorado and northeastern New Mexico with 500mb temperatures of minus 28 degs C over southern New Mexico. See Figure 3.

Snow fell across the Tucson metro area in mainly three bouts, one during the mid to late morning of the 20th, again during the late afternoon and early evening and another during the late evening. By the time the event was over the official snow amount for Tucson that day was 2 inches, with amounts in the 3 to 5 inch range over eastern portions of Pima county...including the Vail area, but especially the foothills. Even lower elevations of the Tucson metro area (around 2,000 feet) received snow.

Snow amounts for some of the peaks across southeast Arizona were as follows:

Kitt Peak…….7 inches

Mt. Lemmon…….12 inches

Mt. Graham……...16 inches

"By the time the event was over the official snow amount for Tucson that day was 2 inches"

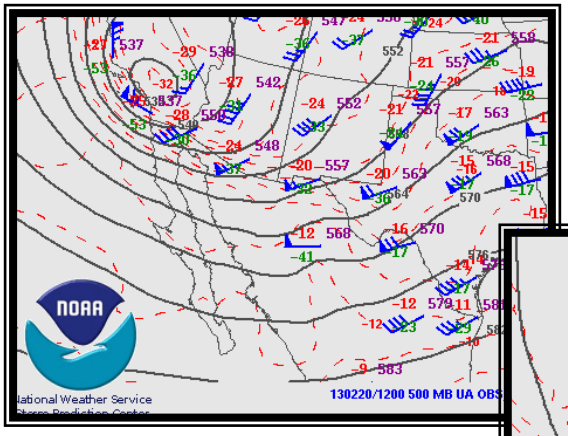

Figure 1. 500mb Heights, Temps and Wind

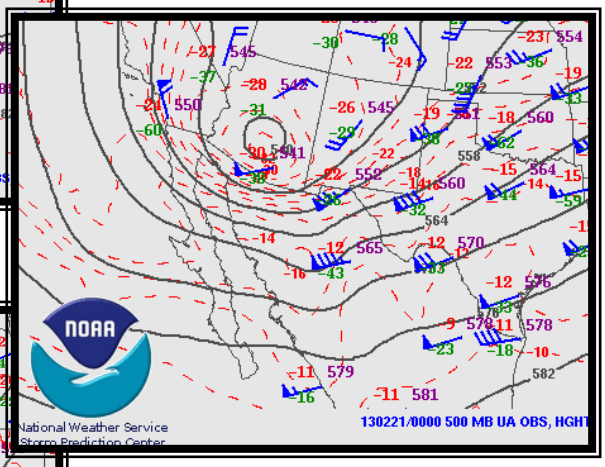

Figure 2. 500mb Heights, Temps and Wind

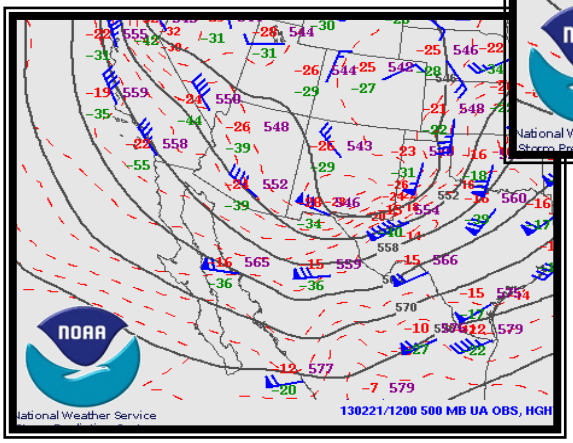

Figure 3. 500mb Heights, Temps and Wind

Major Winter Storm Brings Snow to Southeast Arizona...Including the Tucson Metro Area

Taken near the town of Catalina by our own forecaster, Gary Zell

Beautiful snow over the desert taken by our Service Hydrologist, Erin Boyle

A Cholla cactus covered with snow taken by Erin Boyle

Snow covered saguaro cacti on the east side of the Tucson metro area taken by forecaster, Jerald Meadows

"Snow amounts in the 3 to 5 inch range fell over eastern portions of Pima county...including the Vail area, but especially the foothills".

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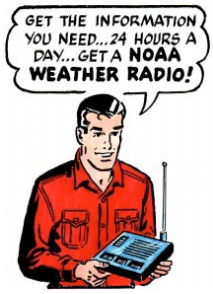
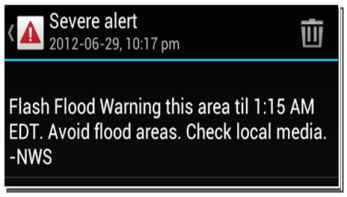
What's That Noise?



Glen Sampson, Meteorologist In Charge



Wireless Emergency Alert (WEA) is a nationwide text emergency alert system for cell phones that was launched in April 2012. A coalition between the FCC, FEMA and wireless providers oversee WEA. Like the Emergency Alert System, which is linked into radio and television broadcasts, activation of this system has audio tones causing people to take notice of its message. WEA is activated for Amber Alerts associated with child abductions, imminent threats like severe weather and Presidential messages in the event of a national emergency. The National Weather Service began passing severe weather warnings to the WEA system in June 2012. For southern Arizona, flash flood and dust storm warnings are the two most common types of severe weather causing WEA activation. Severe thunderstorms do NOT activate WEA. When WEA is activated, cell phones in the affected area will make a loud, unusual noise and display a text message. The text messages are 90 characters or less, indicate the cause of the activation and encourage the recipient of the message to check local media for details.

WEA activations were originally engineered to affect all cell towers in a county where the threat was occurring. In much of the Nation, the small size of counties causes this approach to work well. In the West counties are much larger, and activation for an entire county includes more people than are actually impacted. Hence during the summer of 2012, the wireless providers re-engineered their processing of alerts to use location specific information when available in NWS warnings. Unfortunately not all NWS warnings have this specific information. Flash flood warnings have this information embedded in them, and only cell phones near the impacted area will be activated. Dust storm warnings do not have the same type of location information, and as such an entire county is alerted. The NWS is actively working with partners to ensure your cell phone only activates when severe weather is nearby. WEA has been demonstrated to save lives, and these expected improvements in 2013 will make this system even more effective. for more information on Wireless Emergency Alerts, see

http://www.nws.noaa.gov/com/weatherreadynation/wea.html

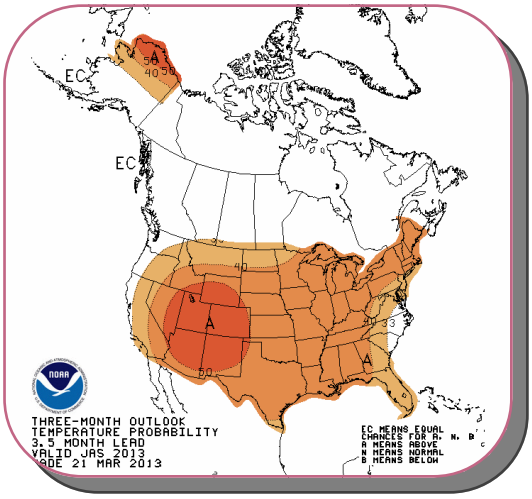
WIRELESS EMERGENCY ALERTS CAPABLE

"When WEA is activated, cell phones in the affected area will make a loud, unusual noise and display a text message."

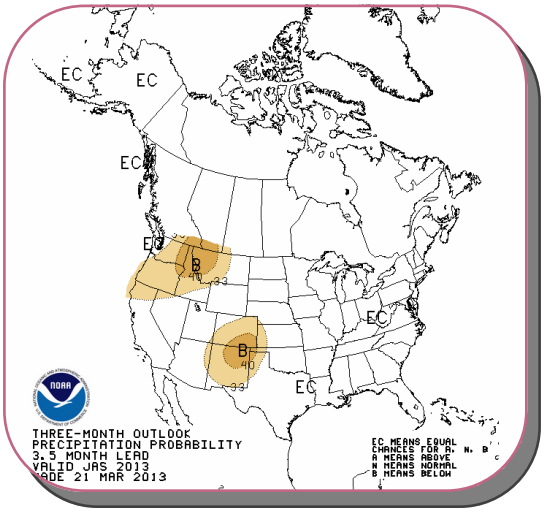
What to Expect This Monsoon

Greg Mollere, Senior Forecaster and SKYWARN Spotter Training Coordinator

The official forecast from the Climate Prediction Center (CPC) for the months of July, August and September of 2013 indicate that there is a greater likelihood that temperatures will be above normal during this period. The forecast for precipitation shows less certainty, and indicates there are equal chances that precipitation will be either above, below or normal for 2013.



Temperature Outlook for July, August and September 2013



Precipitation Outlook for July, August and September 2013

Meteorologist Intern to Make Tucson Home

Emily French, Meteorologist Intern

I grew up in Torrington, CT (Litchfield County) and graduated high school there. I spent a good chunk of my life on Cape Cod as well, working in the summers and taking care of my grandparents. I am a beach bum at heart, and it is the one thing (other than my family) that I miss the most about the northeast. I went to Rutgers University from 2005-2009 and got my B.S. in Meteorology with a minor in marine science. After taking a year off, I followed up with graduate school at the South Dakota School of Mines and Technology and got my M.S. in Atmospheric Science in May 2012. I am currently living in Rapid City, SD.

I really enjoy watching/playing sports and the outdoors. I have been an avid fisherman since I was 6, mostly lake fishing although I have done some stream fishing since being in Rapid City. I have enjoyed deep sea fishing in the past as well. I have been playing volleyball since the age of 12, and hope to continue playing at a somewhat competitive level in Tucson. I like to go hiking and camping on occasion. In terms of sports teams, I remain a New Englander at heart – Red Sox, Patriots, and Celtics. I never really got into hockey, so I can't say that I follow the Bruins at all.

Emily French, Meteorologist Intern

My love of the weather began at a young age – about 10. I have never had second thoughts about becoming a meteorologist, and I hope to be able to share my passion with all of you. I do hope to get more involved in photography, scrapbooking, and canning while I am living in Arizona. These are things I have always wanted to do, but never really had the time for.

"My love of the weather began at a young age – about 10"

-Emily

National Weather Service Tucson Office Staff

Meteorologist in Charge…….Glen Sampson

Administrative Support Assistant…….Stephanie Spease

Warning Coordination Meteorologist…….Kenneth Drozd

Science and Operations Officer…….John Brost

Service Hydrologist…….Erin Boyle

Electronic Systems Analyst…….Chris Carney

IT Specialist…….Evelyn Bersack

Electronic Technicians……Rick Leupold, Keith Sapp

Senior Forecasters…….Jeff Davis, Brian Francis, John Glueck, Jim Meyer, Greg Mollere

General Forecasters…….Glenn Lader, Chris Rasmussen, Carl Cerniglia, Jerald Meadows, Gary Zell

Meteorologist Interns…….Emily French, Ricardo Humphreys

Observation Program Leader…….Mic Sherwood

Hydrometeorological Technician…….Hans Hanson

Dust Storm Workshop Brings NWS and Partners Together

Ken Drozd, Warning Coordination Meteorologist Tucson Forecast Office and
Ken Waters, Warning Coordination Meteorologist, Phoenix Forecast Office

National Weather Service offices in Phoenix and Tucson partnered with the Arizona Department of Transportation to host a Dust Storm Workshop March 5th. The workshop followed up on the successes and goals that came out of the 2012 Dust Storm Workshop and provided participating agencies a chance to evaluate and discuss longer-term initiatives to protect the public before, during and after a dust storm. Dust storms cause accidents on Arizona roadways each year. On average, these accidents lead to two deaths and several injuries each year along with lengthy traffic delays on Interstate 10, a major transportation corridor between Phoenix and Tucson, and a significant trade route across the nation. In addition, dust storms create pollutants which can lead to respiratory difficulties in susceptible populations. About 60 individuals, representing public safety, emergency management, air quality, agriculture, academia, and the research community participated in the workshop to discuss dust storm prevention, detection, prediction, education and response.

To view the Dust Storm Safety video above, go to:

pullasidestayalive.org

"On average, these accidents lead to two deaths and several injuries each year along with lengthy traffic delays on Interstate 10"

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Please keep your personal information up-to-date. Do we have your correct mailing address, location, phone number and e-mail address? If not, please update us so that our database is as current as possible. The best way to update your information is to e-mail me at :

greg.mollere@noaa.gov

Be Prepared this Monsoon. Please Go Through These Safety Rules With You and Your Family

Although the monsoon brings welcome rains and relief from the summer heat, the thunderstorms that come with the monsoon bring their own hazards. This is the most dangerous time of year weather-wise in Arizona, so before and during the season, it is a very good idea to review these safety tips:

Lightning:

If you hear thunder, you are close enough to a storm to be struck by lightning. Go to a safe place immediately! The safest locations are sturdy buildings and hard-topped vehicles.

Get away from open areas, including armadas, porches, trees, convertible cars, swimming pools, and open areas.

Plan outdoor activities to avoid being outside between mid afternoon and mid evening, especially in higher elevations where lightning is more common.

Do not touch any wires or plumbing inside a building

Remember that it does not have to be raining for you to be struck by lightning. Lightning can strike up to 60 miles away from the nearest rainfall!

Bring pets indoors. Lightning and thunder are very scary for pets, and they are likely to panic or even run away to try and escape the storm.

If someone is struck by lightning, call 911 immediately!

Flash Floods:

Flash floods are common in Arizona. There are thousands of low water crossing and dips which flood every summer. Know where they are, and avoid them during heavy rains.

Never ever drive into a flooded roadway. The water depth is very easy to misjudge, and the road itself may be damaged or destroyed underneath. It only takes about 1 to 2 feet of water to float most vehicles, including SUVs.

Never drive around barricades. They are there for a reason – usually because flash flooding is about to take place, is already happening or the road is damaged by flooding and is unsafe.

Never allow children to play near washes or storm drains after any rainfall, no matter how light. These flood easily and rapidly, and storm drains are usually so large that children can be swept away.

Beware of distant thunderstorms, especially if they're over mountains. Flash flooding can occur many miles away from the thunderstorm as the runoff flows into the valleys and deserts.

Do not camp overnight near streams during the monsoon. Although many of our thunderstorms occur during the afternoon and evening, some of our worst flash floods have occurred in the middle of the night.

Hikers and mountain bikers should try to get out early in the day to avoid the dangers of not only flash flooding, but also lightning. Wherever you are hiking during the monsoon, be aware of your escape routes, follow ranger instructions, and be prepared to move to higher ground quickly.

"Never ever drive into a flooded roadway. The water depth is very easy to misjudge"

Dust storms:

These are an underrated killer in Arizona! Straight lines winds in any thunderstorm can lift huge clouds of dust and reduce visibilities to near zero in seconds, which can quickly result in deadly, multi-vehicle accidents on roadways.

Dust storms are more common in the early part of the monsoon, near agricultural areas, and near the Willcox Playa in Cochise County. Use caution in these areas any time thunderstorms are nearby.

If you encounter a dust storm, pull off the road immediately. Turn off your headlights and put your vehicle in "PARK," and take your foot off the brake. Other motorists may tend to follow taillights in an attempt to get through the dust storm, and may strike your vehicle from behind.

Dust storms usually last a few minutes, and up to an hour at most. Stay where you are until the dust storm passes.

Straight-line winds:

Thunderstorm wind gusts in Arizona almost always exceed 40 mph. The strongest straight line wind gusts can exceed 100 mph, and can produce damage similar to a tornado! Anytime a thunderstorm approaches, no matter how weak it seems, move indoors to avoid flying debris. Winds rushing down from a thunderstorm can develop very quickly.

When a Severe Thunderstorm Warning is in effect, it means damaging wind gusts of 60 mph or higher are likely. Move into a central interior room. Stay away from windows.

Unanchored mobile homes are NOT safe in any severe thunderstorm, and even anchored mobile homes can be heavily damaged in winds over 80 mph. Move to a more sturdy structure.

Stay away from trees. The vast majority of people are killed or injured in severe thunderstorms by falling trees, from flying debris, or from downed power lines.

Never touch a downed power line, even if it appears dead. Assume that it is live. Call for help instead.

Straight line winds can travel dozens of miles away from the thunderstorm that produced them. If the wind suddenly shifts and blows toward you from an approaching storm, while the temperature either becomes much colder or much hotter, the winds are likely to become even stronger. Move indoors!

Before the monsoon, it is a good idea to either secure loose outdoor furniture and garbage cans, or move them indoors. These are frequently blown around in our summer thunderstorms – even the weakest ones.

SKYWARN SPOTTER TRAINING SESSIONS

Date	Time	Location
Tue April 9	6:30 pm	Sierra Vista Police Dept. Auditorium 911 N. Coronado Drive Sierra Vista, AZ
Thu April 11	6:30 pm	Graham County Administration Bldg. 921 Thatcher Blvd. Safford, AZ
Mon April 15	6:30 pm	U of A Campus, ENRB 520 N. Park Ave., Room 253 Tucson, AZ
Sat April 20	10:30 am	Ajo Ambulance 1850 North Ajo Gila Bend Highway Ajo, AZ
Mon April 22	6:30 pm	Oracle Fire Department 1475 West American Ave. Oracle, AZ
Mon April 29	6:30 pm	Oro Valley Town Hall Complex Council Chambers 11000 N. La Cañada Drive Oro Valley, AZ
Sat May 4	2:00 pm	U of A Campus, ENRB 520 N. Park Ave., Room 253 Tucson, AZ
Mon May 20	6:30 pm	Santa Cruz County Building 2150 N. Comgress Drive Nogales, AZ
Thu May 23	6:00 pm	Kirk-Bear Canyon Library 8959 E. Tanque Verde Rd. Tucson, AZ
Thu May 30	6:00 pm	City of Douglas Visitor Center 345 16th St. Douglas, AZ
Sat June 1	2:00 pm	Oro Valley Town Library 1305 W. Naranja Oro Valley, AZ

What You As A Skywarn Spotter Should Report??

Tornado: A Tornado or a funnel cloud

Heavy Rain: A Half Inch or more in less than an hour

Hail: Dime size hail or larger

High Wind: Estimated or measured 45 mph or greater

Flooding: Any Kind of Flooding

Snow: One inch or more (2 inches if above 5000 feet)

Visibility: Less than one mile

Death/ Injury: Any weather related reason

Damage: Any weather related reason

(520) 670-5162 or 1-800-238-3747